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(54) A product of a Ti-Al system intermetallic compound having a superior oxidation resistance and wear resistance and a method of manufacturing the product

Erzeugnis aus einer intermetallischen Verbindung des Ti-Al-Systems mit hoher Widerstandsfähigkeit gegen Oxidation und Verschleiss und Verfahren zur Herstellung dieses Erzeugnisses

Produit preparé à partir d'un composé intermétallique du système Ti-Al ayant une résistance élevée à l'oxydation et à l'usure et procédé pour la fabrication de ce produit

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Description

FIELD OF THE INVENTION

This invention relates to a product of a Ti-Al system intermetallic compound which is used in the field of automobile, aerospace, industrial machine tools and others, and further relates to a method of producing a product of the Ti-Al system intermetallic compound, which requires lightweight, high-temperature strength, high rigidity, oxidation resistance and wear resistance.

BACKGROUND OF THE INVENTION

Recently, in the field of automobiles, lightweight and high performance were demanded simultaneously. Especially, the engine components are required to be light in weight.

For example, steel or nickel alloys are used as engine valves. However, these materials are so dense that the inertial mass of the engine valves is large, which hinders an engine from rotating at high speed. By making the engine valves lightweight, the inertial mass of the valves can be reduced. Thus, the engine can be rotated at high speed and an automobile with high performance can be provided. To meet such needs, a Ti-Al system intermetallic compound is highly demanded as a light-weight, heat-resistant material, because this compound has low density and superior strength at high temperature. For such reasons, the compound has been widely researched and developed.

However, the practical use of the Ti-Al intermetallic compound is hindered for the following three reasons:

(1) the compound has an insufficient ductility at room temperature;
(2) the compound is hard to work, thereby difficult to shape into components; and
(3) the component has an insufficient oxidation resistance.

To solve these problems, the Ti-Al system intermetallic compound has been widely and variously researched and developed.

It is now clarified that the addition of manganese, chromium, vanadium or the like can improve the ductility at room temperature of the intermetallic compound.

Japan Laid-open Patent Application No. 1-30898 proposes an improvement in the difficulty in working the Ti-Al system intermetallic compound. The proposed Ti-Al system intermetallic compound is prepared by a reaction sintering process. Specifically, titanium or titanium alloy powder is first mixed with aluminum or aluminum alloy powder, and is then degassed and charged through a vacuum. Subsequently, the mixed powder is plastically deformed at the reacting synthesis temperature or lower temperature. Thus obtained mixed body is heated to the reacting synthesis temperature or a higher temperature.

The improvement in the oxidation resistance of the Ti-Al system intermetallic compound is researched and developed, as seen in the following documents:

(1) Research Report of the 123rd Committee on Heat-resistance Material, Japan Society for the Promotion of Science Vol.29 No.1 (1988), P77-87, in which Tsurumi et al. proves the improvement by the addition of niobium;
(2) Minute of Autumn Conference of the Japan Institute of Metals; Journal Vol.29 (1990), P274, in which Anada et al. proves the improvement by the addition of molybdenum;
(3) Minute of Autumn Conference of the Japan Institute of Metals; Journal Vol.30 (1991), P561, in which Anada et al. proves the improvement by the addition of tungsten; and
(4) Minute of Autumn Conference of the Japan Institute of Metals; Journal Vol.54 No.8 (1990), P948-P954, in which Kasahara et al. proves the improvement by the addition of silicon.

However, such improvements in oxidation resistance are insufficient for the practical use of the Ti-Al system intermetallic compound.

The components disposed around an engine are mostly sliding members. If such components are made of titanium aluminide, they are easily worn, which is a problem in practical use. Lightweight and at the same time wear resistant sliding members are expected.

EP-A-0 413 524 discloses a titanium-aluminum based light weight, heat-resisting material containing, by weight percentage, 30 to 42% of Al, 0.1 to 2% of Si, 0.1 to 5% of Nb and the balance being substantially Ti which may be prepared by using sponge titanium.

SUMMARY OF THE INVENTION

Wherefore, an object of this invention is to provide a product of a Ti-Al system intermetallic compound having a superior oxidation resistance. This compound is claimed in claim 1, with preferred embodiments as claimed in claims 2 to 4. An article formed from this compound is claimed in claim 5 and a method to manufacture the article is claimed in claim 8, with preferred embodiments, respectively.

Another object of the invention is to provide a method of manufacturing a product of a Ti-Al system intermetallic compound, such that the resulting intermetallic compound has a superior oxidation resistance.

Further object of the present invention is to provide a product of lightweight, wear-resistant Ti-Al system intermetallic compound and a method of manufacturing the product.

To attain this or other objects, this invention provides a product of a Ti-Al system intermetallic compound substantially comprising titanium and aluminum. The product is provided with a surface layer including 0.004at.% to 1.0at.% of at least one halogen element selected from the group consisting of fluorine, chlorine, bromine and iodine. Not only the surface of the product, but the entire product itself can include 0.004at.% to 1.0at.% of at least one halogen element selected from the group consisting of fluorine, chlorine, bromine and iodine. The symbol at.% is the ratio of the atoms of the the compound composed of a given element. It is found by dividing the percent by weight of each element in the compound by that elements atomic weight and taking the ratio of the result as at.%. If the amount of the halogen element is less than the lower limit, the oxidation resistance of the compound is insufficient, and if the amount exceeds the upper limit, the elongation of ductility of the compound is lowered.

The Ti-Al system intermetallic compound preferably comprises 25 at.% to 75 at.% of aluminum and the remainder at.% of titanium. If the amount of aluminum is less than the lower limit, the ductility of the compound is decreased, and if the amount exceeds the upper limit, the strength of the compound is decreased.

The Ti-Al system intermetallic compound preferably includes 0.5at.% to 3at.% each of at least one element selected from the group consisting of niobium, molybdenum, tungsten and silicon. If the amount of the element is less than the lower limit, no further improvement in the oxidation resistance of the compound can be expected, and if the amount exceeds the upper limit, no further improvements result from the addition of the element and the density of the compound is increased.

The Ti-Al system intermetallic compound preferably includes 0.5at.% to 3at.% each of at least one element selected from the group consisting of manganese, chromium and vanadium. If the amount of the element is less than the lower limit, no further improvement in the ductility can be expected, and if the amount exceeds the upper limit, no further improvements result from the addition of the element and the density of the compound is increased.

In another embodiment of the invention, a method of manufacturing a product of a Ti-Al intermetallic compound substantially comprising titanium and aluminum, comprises the steps of: introducing at least one halogen element selected from the group consisting of fluorine, chlorine, bromine and iodine into the Ti-Al intermetallic compound; forming the Ti-Al intermetallic compound into a desired shape to produce a product; and oxidizing the surface of the product thus formed.

Alternatively, surface treatment for introducing halogen on the surface of the product may be made.

The method of treating the surface of a Ti-Al system intermetallic compound comprises the steps of: heating the surface of the Ti-Al system intermetallic compound to between 800°C and 1125°C in a mixture gas including 2ppm to 1 % by volume of at least one halogen element selected from the group consisting of fluorine, chlorine, bromine and iodine and including 0.1 % by volume or more of oxygen; and thus forming a dense aluminum oxide film on the surface of the Ti-Al system intermetallic compound.

The reasons for the limitations on the numerical values are now explained.

(1) The amount of the halogen elements is limited as aforementioned, because if the amount is less than the lower limit, an ununiformly thick aluminum oxide film is formed, and if the amount exceeds the upper limit, an imperfect aluminum oxide film is formed. In both cases the oxidation resistance is insufficient.

(2) The amount of oxygen is limited as aforementioned, because if the amount is less than the lower limit, only a thin aluminum oxide film is formed and the oxidation resistance is insufficient.

(3) The treatment temperature is limited as aforementioned, because if the temperature is lower than the lower limit, only a thin aluminum oxide film is formed. If the temperature exceeds the upper limit, the generation of the alpha phase, i.e., alpha solid solution of titanium alloy containing small amounts of aluminum, which tends to be easily oxidized, results in an ununiformly thick aluminum oxide film. In both cases the oxidation resistance is insufficient.

The aforementioned mixture of gas can include nitrogen gas or other inactive gas. Unavoidable foreign particles can be contained in the gas mixture. The inactive gas can be argon gas or other. The gas mixture can contain multiple kinds of inactive gases.

The method of treating the surface of a Ti-Al system intermetallic compound can comprise the steps of: placing a halogen compound including at least one halogen element selected from the group consisting of fluorine, chlorine, bromine and-iodine on the surface of the part, providing the oxidation resistance of the Ti-Al system intermetallic compound, the amount of the halogen compound being between 0.002 mol/m^2 and 2 mol/m^2; heating the Ti-Al system intermetallic compound to between 800°C to 1125°C for 0.2 hour at least; and thus forming a dense aluminum oxide film on the surface of the Ti-Al system intermetallic compound.

The Ti-Al system intermetallic compound is preferably heated in the air.

The halogen compound placed on the surface of the part, providing the oxidation resistance of the Ti-Al system intermetallic compound, is a solid. The intermetallic compound with the solid halogen compound disposed thereon is heated to the melting point of the halogen compound or a higher temperature. Alternatively, the halogen compound can be liquid.

The halogen amount and the treatment temperature are limited as aforementioned, because if these conditions are out of the limited range, only an insufficient oxidation resistance results. If the time period for the surface treatment is less than the lower limit, only a thin aluminum oxide film is formed and an insufficient oxidation resistance results. Further, if the heating process is lengthened over ten hours, no further effect of the formed aluminum oxide film can be expected. Therefore, the heating process need not to be continued longer than ten hours.

In the invention, by adding a halogen including halide, the oxidation resistance of the Ti-Al system intermetallic compound is remarkably enhanced.

To provide a Ti-Al system intermetallic compound having wear resistance, in a further embodiment of the invention, a product of the Ti-Al system intermetallic compound comprises 25at.% to 75at.% of aluminum, 0.004at.% to 1at.% of at least one halogen element selected from the group consisting of fluorine, chlorine, bromine and iodine and the remainder of titanium and unavoidable impurities. A dense aluminum oxide film having a thickness between 1μm and 50μm is formed on the surface of the part, providing the wear resistance of the product.

The product of the Ti-Al system intermetallic compound comprises 0.05at.% to 10at.% of manganese.

Additionally, to provide a Ti-Al system intermetallic compound having a wear resistance, a method of manufacturing a product of the Ti-Al system intermetallic compound comprising 25at.% to 75at.% of aluminum, 0.004at.% to 1at.% of at least one halogen element selected from the group consisting of fluorine, chlorine, bromine and iodine and the remainder of titanium and unavoidable impurities, comprises the steps of oxidizing a Ti-Al system intermetallic compound in the temperature range from 800°C to 1125°C in an oxidizing atmosphere; and forming a dense aluminum oxide film on the surface of the intermetallic compound.

In the method of manufacturing a product of Ti-Al system intermetallic compound, the product further includes 0.05at.% to 10at.% of manganese.

The reasons for the aforementioned limitations of the numerical values are now explained.

(1) The amount of aluminum

If the amount is less than the lower limitation, no continuous aluminum oxide film is formed and an insufficient wear resistance results, and if the amount exceeds the upper limitation, no further wear resistance can be expected.

(2) The amount of halogen

If the amount is less than the lower limitation, an aluminum oxide film having good adhesion to the base fails to be formed and the wear resistance is lowered, and if the amount exceeds the upper limitation, the ductility of the base material is lowered.

(3) The thickness of an aluminum oxide film

If the thickness is less than the lower limitation, the film is too thin to provide a sufficient wear resistance, and if the thickness exceeds the upper limitation, the film is so thick that it easily cracks and provides a low wear resistance.

(4) The amount of manganese

If the amount is less than the lower limitation, the ductility is not enhanced, and if the amount exceeds the upper limitation, no further improvement can be expected.

(5) Thermal treatment (oxidizing) temperature

If the temperature is lower than the lower limitation, only a thin aluminum oxide film is formed and the wear resist-

ance is insufficient, and if the temperature exceeds the upper limitation, a too thick aluminum oxide film is formed, easily cracks and provides a low wear resistance.

The time period for oxidizing treatment preferably ranges from five minutes to 24 hours. If the time period is shorter than the lower limitation, only a thin aluminum oxide film is formed and provides an insufficient wear resistance, and if it exceeds the upper limitation, no further improvement is expected and productivity is decreased in vain.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIRST EMBODIMENT

Sponge titanium powder was mixed with at least one of aluminum powder; aluminum and manganese alloy powder; aluminum and chromium alloy powder; aluminum and niobium alloy powder; aluminum and molybdenum alloy powder; and aluminum and silicon alloy powder. The sponge titanium powder has a particle size of 149µm or less and is prepared by a sodium reduction process. The intermetallic compound included chlorine in the form of sodium chloride. Sodium chloride was unavoidably introduced as residual impurities, while titanium tetrachloride was reduced using sodium to form sponge titanium. The aluminum powder is prepared by an air atomizing process. Each powder to be mixed with the sponge titanium powder has a particle size of 149µm or less. These kinds of powder were mixed in a proportion such that the sample Nos. 1-11 shown in Table 1 were obtained as the final compositions. The mixed powder was introduced in an aluminum container. Subsequently, while being heated, the container was exhausted through a vacuum. After this degassing process, the container including the mixed powder was hot-extruded at 430°C and at the extrusion ratio of 91. The extruded material was then cut out of the aluminum container. A reacting synthesis process was then started from the extruded material: the extruded material was processed by a hot isostatic pressing process at 560°C to form a Ti-Al system intermetallic compound. Subsequently, the intermetallic compound was homogenized by further continued hot isostatic pressing process performed for ten hours at 1300°C. This homogenization was carried out in an atmosphere of argon gas and under a pressure of 180 MPa.

Tension-test pieces were prepared from the sample Nos. 1-11 obtained as aforementioned. The test pieces have a parallel-part diameter of 5mm and a gauge length of 15mm. Tension test was carried out on the test pieces at room temperature, in which the rate of strain was 10^{-3}/second. The elongation of the test pieces were also measured.

Further test pieces having a size of 7mm × 7mm × 15mm were cut from the samples of the Ti-Al system intermetallic compound. The surface of the test pieces was polished with #800 emery paper, and a high temperature oxidation test was carried out for 24 hours at 975°C in the atmosphere. The test results are shown in Table 1.

As shown in Table 1, the sample Nos. 1-11 embodying the invention have an oxidation increase of 15g/m^2 or less. These samples have such a small oxidation increase and are superior in their oxidation resistance.

Especially, the sample Nos. 5-7, including niobium, molybdenum and silicon in the range between 0.5at.% and 3at.%, respectively, have an oxidation increase of 5 to 9 g/m^2 and thus have superior oxidation resistance.

TABLE 1

SAMPLE NO.	CHEMICAL COMPOSITION (at.%) (remainder at.% correspond to the amount of Ti							TENSILE STRENGTH (MPa)	ELONGATION (%)	OXIDATION INCREASE (g/m^2)	OXIDE FILM THICKNESS (µm)
	Cl	Al	Mn	Cr	Nb	Mo	Si				
1	0.10	48	-	-	-	-	-	566	0.5	10	3
2	0.85	48	-	-	-	-	-	572	0.7	7	2
3	0.05	46	2	-	-	-	-	585	1.3	13	4
4	0.10	46	-	2	-	-	-	589	1.2	15	5
5	0.08	41	-	-	3	-	-	579	1.7	5	2
6	0.07	46	-	-	-	2	-	572	0.7	8	3
7	0.04	46	2	-	-	-	0.5	536	0.6	9	4
8	0.03	48	0.4	-	-	-	-	479	0.9	14	5
9	0.04	48	3.2	1.2	-	-	-	595	1.5	15	5
10	0.05	44	-	1.2	3.4	-	-	600	1.9	10	3
11	0.05	48	-	-	-	-	0.3	472	0.3	10	3

SECOND EMBODIMENT

Titanium powder having a particle size of 149µm or less prepared by a hydrogenation-dehydrogenation process was mixed with one of the aluminum powders, prepared by a helium gas atomizing process; aluminum and vanadium alloy powder; aluminum and silicon alloy powder; tungsten powder; and aluminum and manganese alloy powder; each having a particle size of 149µm or less, in a proportion such that the sample Nos. 12-17 shown in Table 2 were obtained as the final chemical compositions.

The intermetallic compound included chlorine in the form of magnesium chloride. Magnesium chloride was unavoidably introduced as residual impurities while titanium powder was,produced. The sample No. 17 in Table 2 was obtained by adding zinc fluoride having an average particle size of 0.3µm as a halide at the first stage of the process. Subsequently, the mixed powder was introduced in an aluminum container. While being heated, the container was exhausted through a vacuum. After this degassing process, the aluminum container containing the mixed powder was hot-extruded at 400°C and at the extrusion ratio of 63. The extruded material was then cut out of the container. A reacting synthesis process was then started from the extruded material: the extruded material was processed by hot isostatic pressing process at 560°C to form a Ti-Al system intermetallic compound. Subsequently, the intermetallic compound was homogenized by further continued hot isostatic pressing process performed for twelve hours at 1250°C. This homogenization was carried out in an atmosphere of argon gas and under a pressure of 160 MPa.

In the same way as in the first embodiment, the tension test pieces were prepared, the tension test was conducted, and the elongation of the test pieces was also measured. Further, the high temperature oxidation test was carried out. The test results are shown in Table 2.

As clearly shown in Table 2, the sample Nos. 12-17 have a remarkably small oxidation increase of 25g/m^2 or less and are preferably superior in oxidation resistance.

Especially, the sample Nos. 14-16, including silicon or tungsten in the range between 0.5at.% and 1.5at.%, have a remarkably small oxidation increase of 7 g/m^2 and thus have superior oxidation resistance.

TABLE 2

SAMPLE NO.	CHEMICAL COMPOSITION (at.%) (remainder at.% correspond to the amount of Ti)							TENSILE STRENGTH (MPa)	ELONGATION (%)	OXIDATION INCREASE (g/m^2)	OXIDE FILM THICKNESS (μm)
	F	Cl	Al	Mn	V	Si	W				
12	-	0.006	48	-	-	-	-	572	0.7	25	35
13	-	0.01	46	-	2	-	-	595	1.0	21	24
14	-	0.03	47	-	-	0.5	-	559	0.6	7	3
15	-	0.01	47	-	-	-	0.5	548	0.5	7	3
16	-	0.01	47	-	-	-	1.5	568	0.5	7	3
17	0.05	0.003	48	2	-	-	-	498	0.5	12	4

THIRD EMBODIMENT

Titanium powder having a particle size of 149µm or less prepared by a plasma rotating electrode process was mixed with at least one of the aluminum powders prepared by a helium gas atomizing process; aluminum and manganese alloy powder; aluminum and silicon alloy powder; and aluminum, niobium and silicon alloy powder, each having a particle size of 149µm or less: and was further mixed with a halide powder having a particle size of 2µm, in a proportion such that the sample Nos. 18-21 shown in Table 3 were obtained as the final chemical compositions.

At this stage, as the halide powder, zinc fluoride was used to form sample No. 18, sodium chloride was used to form sample No. 19, silver bromide was used to form sample No. 20, and silver iodide was used to form sample No. 21.

Subsequently, the mixed powder was introduced in an aluminum container. While being heated, the container was exhausted through a vacuum. After this degassing process, the aluminum container containing the mixed powder was hot-extruded at 400°C and at the extrusion ratio of 63. The extruded material was cut out of the container. A reacting synthesis process was then started from the extruded material: the extruded material was processed by a hot isostatic pressing process at 560°C to form a Ti-Al system intermetallic compound. Subsequently, the intermetallic compound was homogenized by further continued hot isostatic pressing process performed for two hours at 1300°C. This homogenization was carried out in an atmosphere of argon gas and under a pressure of 150 MPa.

In the same way as in the first embodiment, the tension test pieces were prepared, the tension test was conducted, and the elongation of the test pieces was also measured. Further, the high temperature oxidation test was carried out. The test results are shown in Table 3.

As clearly shown in Table 3, the sample Nos. 18-21 have a small oxidation increase of 25g/m^2 or less and are preferably superior in oxidation resistance.

TABLE 3

SAMPLE NO.	CHEMICAL COMPOSITION (at.%) (remainder at.% correspond to the amount of Ti)								TENSILE STRENGTH (MPa)	ELONGATION (%)	OXIDATION INCREASE (g/m²)	OXIDE FILM THICKNESS (μm)
	F	Cl	Br	I	Al	Mn	Nb	Si				
18	0.1	-	-	-	48	-	-	-	489	0.3	18	12
19	-	0.05	-	-	46	2	-	-	505	1.0	14	4
20	-	-	0.04	-	47	-	-	0.5	512	0.4	20	21
21	-	-	-	0.01	41	-	3	0.5	531	0.9	25	40

FIRST REFERENCE EXAMPLE

In the same way as the second embodiment, the sample No. 22 of the Ti-Al system intermetallic compound containing a small amount of chlorine was prepared.

In the same way as the second embodiment, the tension test piece was cut from the sample No. 22, the tension test was carried out and the elongation was also measured. Further, the high temperature oxidation test was conducted. The test results are shown in Table 4, which also shows second and third reference examples described later.

As clearly shown in Table 4, the sample No. 22 has a remarkably large oxidation increase of 286g/m^2 and is undesirably inferior in oxidation resistance.

SECOND REFERENCE EXAMPLE

In the same way as the third embodiment, sample No. 23 containing a relatively small amount of chlorine and sample No. 24 containing a large amount of halogen element were prepared.

In the same way as the third embodiment, the tension test pieces were prepared from the samples, the tension tests were carried out and the elongations were also measured. Further, the high temperature oxidation test was conducted. The test results are shown in Table 4.

As clearly shown in Table 4, the sample No. 23 has a remarkably large oxidation increase of 268g/m^2 and is undesirably inferior in oxidation resistance. The sample No. 24 unfavorably has a small elongation of 0% and is inferior in ductility.

THIRD REFERENCE EXAMPLE

By an ingot process, titanium, aluminum and manganese were blended in such a composition that 51at.% of titanium, 47.3at.% of aluminum and 1.7at.% of manganese were included. Thus obtained metal was rolled over three times and dissolved by a plasma arc dissolution.

Specifically, one output of an arc power source is connected to a metal ingot to be dissolved, and the other output is connected to an electrode disposed at a specified distance from the ingot. When a specified voltage is applied from the arc source, an arc is generated between the ingot and the electrode. By introducing argon, hydrogen or nitrogen gas into the region of arc generation, the gas is made into a plasma jet for dissolving the ingot.

If the ingot is dissolved only once, the content of the ingot is segregated. Therefore, the dissolving is discontinued, the ingot is rolled over and the dissolving is resumed. This process was repeated three times in this example and other embodiments.

Thus, sample No. 25 of ingot containing little chlorine was obtained.

In the same way as the third embodiment, the tension test piece was prepared from the sample, the tension test was carried out and the elongation was also measured. Further, the high temperature oxidation test was conducted. The test results are shown in Table 4.

As clearly shown in Table 4, the sample No. 25 has a remarkably large oxidation increase of 342g/m^2 and is undesirably inferior in oxidation resistance.

TABLE 4

SAMPLE NO.	CHEMICAL COMPOSITION (at. %) (remainder at.% correspond to the amount of Ti)			TENSILE STRENGTH (MPa)	ELONGATION (%)	OXIDATION INCREASE (g/m^2)	OXIDE FILM THICKNESS (μm)
	Cl	Al	Mn				
22	0.003	46	2	576	1.3	286	160*
23	<0.001	48	-	554	0.7	268	140*
24	1.1	47	-	441	0	20	6
25	<0.001	46	2	570	1.5	342	241*

NOTE: *THESE OXIDE FILMS ARE FILMS OF BOTH ALUMINUM OXIDE AND TITANIUM OXIDE, NOT OF ALUMINUM OXIDE ONLY.

As aforementioned, the Ti-Al system intermetallic compounds embodying the invention include 0.004at.% to 1.0at.% of a halogen element. Thus, the oxidation resistance of the compounds is enhanced. The compounds are superior to ordinary heat-resistant steels in oxidation resistance, have almost the same oxidation resistance as that of heat-resistance alloys having a base of nickel, and are appropriately light-weight, heat-resistant materials. If the aforemen-

tioned tests of the embodiments are applied to a heat-resistant SUH35 steel and Nimonic[R] alloy, the steel and the alloy indicate the oxidation increase of 45g/m^2 and 15g/m^2, respectively.

FOURTH EMBODIMENT

First, titanium and aluminum were blended, such that the obtained metal was composed of 50 at.% of titanium and 50 at.% of aluminum.

The metal was rolled over three times and dissolved by a plasma arc dissolution, to form an ingot.

A test piece having a size of 7mm × 7mm × 15mm was cut from the ingot, and the surface of the test piece was polished with #800 emery paper. The polished test piece was heated at 875°C for twelve hours in an atmosphere containing 50ppm of fluorine, 20% by volume of oxygen and the remainder of nitrogen. Thus, an oxidation-resistant aluminum oxide film was formed on the surface of the test piece.

This test piece was again heated at 950°C for 24 hours in the air. The oxidation increase of the test piece after the heating process was measured. The test piece is shown in Table 5, as sample No. 26.

FIFTH EMBODIMENT

First, titanium, aluminum and manganese were blended, such that the obtained metal was composed of 51 at.% of titanium, 47.3 at.% of aluminum and 1.7 at.% of manganese.

In the same way as the fourth embodiment, an ingot was formed from the metal. A test piece having a diameter of 4mm and a length of 15mm was cut from the ingot, and the surface of the test piece was polished with #800 emery paper.

The polished test piece was heated at 950°C for four hours in an atmosphere containing 200ppm of chlorine, 20% by volume of oxygen and the remainder of nitrogen. Thus, an aluminum oxide film was formed on the surface of the test piece.

Subsequently, in the same way as the fourth embodiment, the oxidation increase of the test piece after the heating process was measured. The test piece is shown in Table 5, as sample No. 27.

SIXTH EMBODIMENT

First, titanium, aluminum and chromium were blended, such that the obtained metal was composed of 50.7 at.% of titanium, 47.8 at.% of aluminum and 1.5 at.% of chromium.

Subsequently, in the same way as the fifth embodiment, an ingot was formed from the metal, a test piece was cut from the ingot, and the surface of the test piece was polished.

The polished test piece was heated at 1000°C for thirty minutes in an atmosphere containing 500ppm of bromine and the remainder of oxygen. Thus, an aluminum oxide film was formed on the surface of the test piece.

Subsequently, in the same way as the fourth embodiment, the oxidation increase of the test piece after the heating process was measured. The test piece is shown in Table 5, as sample No. 28.

SEVENTH EMBODIMENT

First, titanium, aluminum and vanadium were blended, such that the obtained metal was composed of 51.0 at.% of titanium, 46.7 at.% of aluminum and 2.3 at.% of vanadium.

Subsequently, in the same way as the fifth embodiment, an ingot was formed from the metal, a test piece was cut from the ingot, and the surface of the test piece was polished.

The polished test piece was heated at 750°C for thirty hours in an atmosphere containing 8000 ppm of iodine, 100 ppm of oxygen and the remainder of nitrogen. Thus, an aluminum oxide film was formed on the surface of the test piece.

Subsequently, in the same way as the fourth embodiment, the oxidation increase of the test piece after the heating process was measured. The test piece is shown in Table 5, as sample No. 29.

EIGHTH EMBODIMENT

First, titanium and aluminum were blended, such that the obtained metal was composed of 50 at.% of titanium and 50 at.% of aluminum.

Subsequently, in the same way as the fifth embodiment, an ingot was formed from the metal, a test piece was cut from the ingot, and the surface of the test piece was polished.

The polished test piece was heated at 1000°C for one hundred minutes in an atmosphere containing 20 ppm of fluorine, 1000 ppm of chlorine, 1% by volume of oxygen and the remainder of nitrogen. Thus, an aluminum oxide film

was formed on the surface of the test piece.

Subsequently, in the same way as the fourth embodiment, the oxidation increase of the test piece after the heating process was measured. The test piece is shown in Table 5, as sample No. 30.

NINTH THROUGH ELEVENTH EMBODIMENTS

Test pieces were prepared as sample Nos. 31-33 shown in Table 5. For the composition of the Ti-Al system intermetallic compound and the atmosphere for the surface treatment, refer to Table 5.

The other conditions were the same as those of the fourth embodiment. Thus, an aluminum oxide film was formed on the surface of the test piece.

Subsequently, in the same way as the fourth embodiment, the oxidation increase of the test piece after the heating process was measured. The test conditions and results are shown in Table 5.

FOURTH REFERENCE EXAMPLE

First, titanium and aluminum were blended, such that the obtained metal was composed of 50 at.% of titanium and 50 at.% of aluminum.

Subsequently, in the same way as the fifth embodiment, an ingot was formed from the metal, a test piece was cut from the ingot, and the surface of the test piece was polished.

The polished test piece was heated at 1000°C for six hours in an atmosphere containing 1 ppm of fluorine and the remainder of oxygen. Thus, an aluminum oxide film was formed on the surface of the test piece.

Subsequently, in the same way as the fourth embodiment, the oxidation increase of the test piece after the heating process was measured. The test piece is shown in Table 5, as sample No. 34.

FIFTH REFERENCE EXAMPLE

First, titanium, aluminum and manganese were blended, such that the obtained metal was composed of 51 at.% of titanium, 47.3 at.% of aluminum and 1.7 at.% of manganese.

Subsequently, in the same way as the fifth embodiment, an ingot was formed from the metal, a test piece was cut from the ingot, and the surface of the test piece was polished.

The polished test piece was heated at 850°C for ten hours in an atmosphere containing 1.1 % by volume of chlorine, 20 % by volume of oxygen and the remainder of nitrogen. Thus, an aluminum oxide film was formed on the surface of the test piece.

Subsequently, in the same way as the fourth embodiment, the oxidation increase of the test piece after the heating process was measured. The test piece is shown in Table 5, as sample No. 35.

SIXTH REFERENCE EXAMPLE

First, titanium and aluminum were blended, such that the obtained metal was composed of 50 at.% of titanium and 50 at.% of aluminum.

Subsequently, in the same way as the fifth embodiment, an ingot was formed from the metal, a test piece was cut from the ingot, and the surface of the test piece was polished.

The polished test piece was heated at 725°C for two hours in an atmosphere containing 500 ppm of bromine, 5 ppm of oxygen and the remainder of nitrogen. Thus, an aluminum oxide film was formed on the surface of the test piece.

Subsequently, in the same way as the fourth embodiment, the oxidation increase of the test piece after the heating process was measured. The test piece is shown in Table 5, as sample No. 36.

SEVENTH REFERENCE EXAMPLE

First, titanium, aluminum and manganese were blended, such that the obtained metal was composed of 51 at.% of titanium, 47.3 at.% of aluminum and 1.7 at.% of manganese.

Subsequently, in the same way as the fifth embodiment, an ingot was formed from the metal, a test piece was cut from the ingot, and the surface of the test piece was polished.

The polished test piece was heated at 900°C for twenty hours in an atmosphere containing 20 % by volume of oxygen and the remainder of nitrogen. Thus, an aluminum oxide film was formed on the surface of the test piece.

Subsequently, in the same way as the fourth embodiment, the oxidation increase of the test piece after the heating process was measured. The test piece is shown in Table 5, as sample No. 37.

TABLE 5

SAMPLE NO.	CHEMICAL COMPOSITION OF Ti-Al SYSTEM INTERMETALLIC COMPOUND [AT.%] (Remainder at.% corresponds to the amount of Ti.)	ATMOSPHERE FOR SURFACE TREATMENT [% BY VOLUME]						OXIDATION INCREASE [g/m^2]	OXIDE FILM THICKNESS [μm]
		F	Cl	Br	I	O	REMAINDER		
26	Ti-50Al	0.005	-	-	-	20	N_2	8	4
27	Ti-47.3Al-1.7Mn	-	0.02	-	-	20	N_2	5	3
28	Ti-47.8Al-1.5Cr	-	-	0.05	-	REMAINDER	-	6	3
29	Ti-46.7Al-2.3V	-	-	-	0.8	0.01	N_2	10	4
30	Ti-50Al	0.002	0.1	-	-	1	N_2	3	2
31	Ti-50Al	-	0.5	-	-	20	Ar	8	4
32	Ti-46.8Al-2.1Mn	-	-	0.04	-	0.1	Ar	10	5
33	Ti-47.8Al-1.5Cr	0.01	-	-	-	0.1	Ar	10	4
34	Ti-50Al	0.0001	-	-	-	REMAINDER	-	124	135*
35	Ti-47.3Al-1.7Mn	-	1.1	-	-	20	N_2	78	97*
36	Ti-50Al	-	-	0.05	-	0.0005	N_2	59	36*
37	Ti-47.3Al-1.7Mn	-	-	-	-	20	N_2	240	155*

NOTE:* These films include titanium oxide in addition to aluminum oxide.

As shown in Table 5, the sample Nos. 26-33 embodying the invention have a relatively small oxidation increase of 10 g/m^2 or less and are superior in the oxidation resistance.

However, the sample Nos. 34-37 of the reference examples have a large oxidation increase of 59 g/m^2 and are unfavorably inferior in their oxidation resistance.

TWELFTH EMBODIMENT

First, titanium and aluminum were blended, such that the obtained metal was composed of 50 at.% of titanium and 50 at.% of aluminum.

The metal was rolled over three times and dissolved by a plasma arc dissolution, to form an ingot.

The test piece having a size of 7mm × 7mm × 15mm was cut from the ingot, and the surface of the test piece was polished with #800 emery paper.

Subsequently, the polished test piece was introduced into a crucible, such that at least three corners of the bottom of the piece were supported by the inner face of the crucible. After 140mg of a solid manganese chloride was laid on the upper surface of the piece, the crucible was heated at 900°C, the temperature higher than the melting point of manganese chloride, for two hours in the air. Thus, manganese chloride was applied onto the entire surfaces of the piece.

As a result, manganese chloride was melted and applied onto the surface of the test piece. The amount of the halogen element disposed on the surface of the test piece was 1.208 mol/m^2, which value is obtained by dividing the mol number of 140mg of the melted manganese chloride by the entire surface area of the test piece.

After the aforementioned heating process, the test piece was cut, and its cross section was polished and observed. It was confirmed that an oxidation-resistant aluminum oxide film having the thickness of about 2μm was formed on the surface of the test piece.

Subsequently, the test piece was heated at 950°C for 24 hours in the air, and the oxidation increase after the heating process was measured. Table 6 shows the test conditions and results of the test piece as sample No. 38.

The amount of the halogen element in the test piece can be obtained in the following equation (1):

$$C=(W/(M_O \cdot A)) \cdot M_H/M_O \qquad (1),$$

in which

- C denotes the halogen amount [mol/m^2] per unit area;
- W denotes the addition amount [g] of a halogen compound;
- A denotes the surface area [m^2] of a test piece;
- M_O denotes the molecular weight [g] of the halogen compound; and
- M_H denotes the molecular weight [g] of the halogen element in the halogen compound.

THIRTEENTH EMBODIMENT

First, titanium, aluminum and manganese were blended, such that the obtained metal was composed of 51 at.% of titanium, 47.3 at.% of aluminum and 1.7 at.% of manganese.

In the same way as the twelfth embodiment, an ingot was formed, a test piece was cut out of the ingot, and the surface of the test piece was polished.

Subsequently, 14.6mg of a solid zinc fluoride was laid on the upper surface of the polished test piece, and was then heated at 1000°C for thirty minutes in the air. Thus, an oxidation-resistant aluminum oxide film was formed on the surface of the test piece.

Subsequently, in the same way as the twelfth embodiment, the oxidation increase after the heating process was measured. Table 6 shows the test conditions and results of the test piece as sample No. 39.

FOURTEENTH EMBODIMENT

First, titanium, aluminum and manganese were blended, such that the obtained metal was composed of 50.7 at.% of titanium, 47.9 at.% of aluminum and 1.4 at.% of manganese.

In the same way as the twelfth embodiment, an ingot was formed, a test piece was cut out of the ingot, and the surface of the test piece was polished.

Subsequently, 2.29mg of a solid silver bromide was laid on the polished test piece, and was then heated at 725°C

for five hours in the air. Thus, an oxidation-resistant aluminum oxide film was formed on the surface of the test piece.

Subsequently, in the same way as the twelfth embodiment, the oxidation increase after the heating process was measured. Table 6 shows the test conditions and results of the test piece as sample No. 40.

EIGHTH REFERENCE EXAMPLE

First, titanium and aluminum were blended, such that the obtained metal was composed of 50 at.% of titanium and 50 at.% of aluminum.

In the same way as the twelfth embodiment, an ingot was formed, a test piece was cut out of the ingot, and the surface of the test piece was polished.

Subsequently, 0.05 mg of a sodium chloride was laid on the upper surface of the polished test piece, and was then heated at 900°C for two hours in the air. Thus, an oxidation-resistant aluminum oxide film was formed on the surface of the test piece.

Subsequently, in the same way as the twelfth embodiment, the oxidation increase after the heating process was measured. Table 6 shows the test conditions and results of the test piece as sample No. 41.

NINTH REFERENCE EXAMPLE

In the same way as the eighth reference example, a test piece composed of 50 at.% of titanium and 50 at.% of aluminum was prepared.

Subsequently, 244mg of a solid potassium chloride was laid on the upper surface of the polished test piece, and was then heated at 1000°C for thirty minutes in the air. Thus, an oxidation-resistant aluminum oxide film was formed on the surface of the test piece.

Subsequently, in the same way as the twelfth embodiment, the oxidation increase after the heating process was measured. Table 6 shows the test conditions and results of the test piece as sample No. 42.

TENTH REFERENCE EXAMPLE

In the same way as the eighth reference example, a test piece composed of 50 at.% of titanium and 50at.% of aluminum was prepared.

Subsequently, 22.5mg of a solid silver iodide was laid on the upper surface of the polished test piece, and was then heated at 675°C for three hours in the air. Thus, an oxidation-resistant aluminum oxide film was formed on the surface of the test piece.

Subsequently, in the same way as the twelfth embodiment, the oxidation increase after the heating process was measured. Table 6 shows the test conditions and results of the test piece as sample No. 43.

ELEVENTH REFERENCE EXAMPLE

In the same way as the twelfth embodiment, a test piece composed of 51 at.% of titanium, 47.3 at.% of aluminum and 1.7 at.% of manganese was prepared.

Subsequently, 160mg of a solid zinc fluoride was laid on the upper surface of the polished test piece, and was then heated at 1150°C for two hours in the air. Thus, an oxidation-resistant aluminum oxide film was formed on the surface of the test piece.

Subsequently, in the same way as the twelfth embodiment, the oxidation increase after the heating process was measured. Table 6 shows the test conditions and results of the test piece as sample No. 44.

TWELFTH REFERENCE EXAMPLE

In the same way as the eighth reference example, a test piece composed of 50 at.% of titanium and 50 at.% of aluminum was prepared and polished, with no surface treatment by means of a halogen compound applied thereon.

Subsequently, in the same way as the twelfth embodiment, the oxidation increase after the heating process was measured. Table 6 shows the test conditions and results of the test piece as sample No. 45.

THIRTEENTH REFERENCE EXAMPLE

In the same way as the eleventh example, a test piece composed of 51 at.% of titanium, 47.3 at.% of aluminum and 1.7 at.% of manganese was prepared and polished, without treating the surface thereof using a halogen compound.

Subsequently, in the same way as the twelfth embodiment, the oxidation increase after the heating process was

measured. Table 6 shows the test conditions and results of the test piece as sample No. 46.

TABLE 6

SAMPLE NO.		CHEMICAL COMPOSITION OF Ti-Al SYSTEM INTERMETALLIC COMPOUND [AT.%] (Remainder at.% corresponds to the amount of Ti.)	COMPOUND KIND	HALOGEN AMOUNT [mol/m²]	SURFACE TREATMENT CONDITIONS		OXIDATION INCREASE [g/m²]
					TEMPERATURE [°C]	TIME [h]	
EMBODIMENTS	38	Ti-50Al	$MnCl_2$	1.2	900	2	5
EMBODIMENTS	39	Ti-47.3Al-1.7Mn	ZnF_2	0.1	1000	0.5	6
EMBODIMENTS	40	Ti-47.9Al-1.4Mn	AgBr	0.01	725	5	7
REFERENCES	41	Ti-50Al	NaCl	0.001	900	2	135
REFERENCES	42	Ti-50Al	KCl	3	1000	0.5	98
REFERENCES	43	Ti-50Al	AgI	0.1	675	3	126
REFERENCES	44	Ti-47.3Al-1.7Mn	ZnF_2	1.1	1150	2	340
REFERENCES	45	Ti-50Al	NIL				148
REFERENCES	46	Ti-47.3Al-1.7Mn	NIL				244

As shown in Table 6, the sample Nos. 38-40 embodying the invention have an oxidation increase of 7 g/m^2 or less and are favorably superior in oxidation resistance.

On the other hand, the sample Nos. 41-46 of the reference examples have an oxidation increase of 98 g/m^2 or more and are unfavorably inferior in oxidation resistance.

FIFTEENTH EMBODIMENT

Sponge titanium powder including sodium chloride as impurities, having a particle size of 149μm or less and prepared by a sodium reduction process was mixed with aluminum powder or aluminum alloy powder, which was prepared by the helium atomizing process and has a particle size of 149μm or less, in a proportion such that sample Nos. 48, 52, 53 and 63 shown in Table 7 were obtained as the final compositions. The mixed powder was introduced in an aluminum container. Subsequently, while being heated, the container was exhausted through a vacuum. After this

deaeration process, the container including the mixed powder was hot-extruded at 430°C and at the extrusion ratio of 45. The extruded material was then cut out of the aluminum container. Reacting synthesis process was then started from the extruded material: the extruded material was processed by a hot isostatic pressing process at 560°C to form a Ti-Al system intermetallic compound. Subsequently, the intermetallic compound was homogenized by further continued hot isostatic pressing process performed for ten hours at 1300°C. This homogenization was carried out in an atmosphere of argon gas and under a pressure of 180 MPa. Subsequently, an oxidizing treatment was performed on the surface of the intermetallic compound in the atmosphere under the conditions given in Table 7, so that an aluminum oxide film was formed on the surface of the intermetallic compound.

SIXTEENTH EMBODIMENT

The titanium powder which was prepared by a plasma rotating electrode process and has a particle size of 297μm or less was mixed with aluminum powder or aluminum alloy powder which was prepared by an argon gas atomizing process and has a particle size of 149μm or less, and was mixed further with zinc fluoride powder having a particle size of 149μm or less, in a proportion such that the sample Nos. 47, 50, 51 and 62 shown in Table 7 were obtained as the final chemical compositions.

Subsequently, the mixed powder was introduced in an aluminum container. While being heated, the container was exhausted through a vacuum. After this deaeration process, the aluminum container containing the mixed powder was hot-extruded at 400°C and at the extrusion ratio of 45. The extruded material was then cut out of the container. Reacting synthesis process was then started from the extruded material: the extruded material was processed by a hot isostatic pressing process at 560°C to form a Ti-Al system intermetallic compound. Subsequently, the intermetallic compound was homogenized by further continued hot isostatic pressing process performed for ten hours at 1200°C. This homogenization was carried out in an atmosphere of argon gas and under a pressure of 150 MPa. Subsequently, an oxidizing treatment was performed on the surface of intermetallic compound in the atmosphere under the conditions given in Table 7, so that an aluminum oxide film was formed on the surface of the intermetallic compound.

SEVENTEENTH EMBODIMENT

A powder having a particle size of 74μm, or less, and being prepared by hydrogenating-dehydrogenating the sponge titanium prepared by Kroll's process, was mixed with aluminum powder or aluminum alloy powder, which was prepared by a helium atomizing process and has a particle size of 149μm or less, and was mixed further with silver bromide powder having a particle size of 25μm or less, in a proportion such that sample Nos. 49, 54 and 55 shown in Table 7 was obtained as the final composition. The mixed powder was then introduced in an aluminum container. Subsequently, while being heated, the container was exhausted through a vacuum. After this deaeration process, the container including the mixed powder was hot-extruded at 360°C and at the extrusion ratio of 45. The extruded material was then cut out of the aluminum container. A reacting synthesis process was then started from the extruded material: the extruded material was processed by a hot isostatic pressing process at 560°C to form a Ti-Al system intermetallic compound. Subsequently, the intermetallic compound was homogenized by further continued hot isostatic pressing process performed for ten hours at 1200°C. This homogenization was carried out in an atmosphere of argon gas and under a pressure of 150 MPa. Subsequently, an oxidizing treatment was performed on the surface of intermetallic compound in the atmosphere under the conditions given in Table 7, so that an aluminum oxide film was formed on the surface of the intermetallic compound.

EIGHTEENTH EMBODIMENT

Titanium powder which was prepared by a plasma rotating electrode process and has a particle size of 297μm or less was mixed with aluminum powder or aluminum alloy powder which was prepared by an argon gas atomizing process and has a particle size of 74μm or less, and was mixed further with silver iodide powder having a particle size of 74μm or less, in a proportion such that the sample Nos. 56, 57, 58 and 64 shown in Table 7 was obtained as the final chemical composition.

Subsequently, the mixed powder was introduced in an aluminum container. While being heated, the container was exhausted through a vacuum. After this deaeration process, the aluminum container containing the mixed powder was hot-extruded at 400°C and at the extrusion ratio of 45. The extruded material was then cut out of the container. A reacting synthesis process was then started from the extruded material: the extruded material was processed by a hot isostatic pressing process at 560°C to form a Ti-Al system intermetallic compound. Subsequently, the intermetallic compound was homogenized by further continued hot isostatic pressing process performed for ten hours at 1300°C. This homogenization was carried out in an atmosphere of argon gas and under a pressure of 200 MPa. Subsequently, an oxidizing treatment was performed on the surface of intermetallic compound in the atmosphere under the conditions

given in Table 7, so that an aluminum oxide film was formed on the surface of the intermetallic compound.

THE NINETEENTH EMBODIMENT

The following three kinds of mixture powder were prepared.

The first mixture powder was prepared by mixing sponge titanium powder, aluminum powder and zinc fluoride powder, these material powder having the particle size of 149µm or less, in a proportion such that the sample No. 59 in Table 7 was obtained as the final chemical composition. The sponge titanium powder was prepared by the sodium reduction process, and sodium chloride as unavoidable impurities was introduced into the powder during the process. The aluminum powder was prepared by the helium atomizing process.

The second mixture powder was prepared: the powder having the particle size of 74µm or less and being prepared by hydrogenating-dehydrogenating the sponge titanium prepared by Kroll's process was mixed with aluminum powder prepared by the helium gas atomizing process, silver bromide powder, and the silver iodide powder, in a proportion such that the sample No. 60 shown in Table 7 was obtained as the final chemical composition. The aluminum powder has the particle size of 149µm or less; the silver bromide powder 25µm or less; and silver iodide powder 74µm.

The third mixture powder was prepared: the titanium powder which was prepared by the plasma rotating electrode process and has the particle size of 297µm or less was mixed with aluminum powder which was prepared by the argon gas atomizing process and has the particle size of 74µm or less, and was mixed further with zinc fluoride powder, silver bromide powder and silver iodide powder, in a proportion such that the sample No. 61 in Table 7 was obtained as the final chemical composition. The zinc fluoride powder has the particle size of 149µm or less; the silver bromide powder 25µm or less; and the silver iodide powder 74µm or less.

The three kinds of the mixed powder were introduced in an aluminum container, respectively. Subsequently, while being heated, the container was exhausted through a vacuum. After this deaeration process, the container including the mixed powder was hot-extruded at 400°C and at the extrusion ratio of 45. Thus extruded material was then cut out of the aluminum container. Reacting synthesis process was then started from the extruded material: the extruded material was processed by the hot isostatic pressing process at 560°C to form a Ti-Al system intermetallic compound. Subsequently, the intermetallic compound was homogenized by further continued hot isostatic pressing process performed for ten hours at 1300°C. This homogenization was carried out in the atmosphere of argon gas and under the pressure of 200 MPa. Subsequently, the oxidizing treatment was made on the surface of the intermetallic compound in the atmosphere under the conditions given in Table 7, so that an aluminum oxide film was formed on the surface of the intermetallic compound.

REFERENCE EXAMPLES (SAMPLE NOS. 65-81)

As reference examples, the sample Nos. 65-81 shown in Table 8 were prepared: the sample Nos. 66, 69 and 75 were prepared in the same way as the aforementioned fifteenth embodiment; the sample Nos. 65, 68, 74, 80 and 81 were prepared in the same way as the sixteenth embodiment; the sample Nos. 76 and 77 were prepared in the same way as the seventeenth embodiment; the sample Nos. 67, 70, 78 and 79 were prepared in the same way as the eighteenth embodiment. The sample No. 71 was prepared in the same way as the eighteenth embodiment but has no silver iodide added; the sample No. 72 was prepared in the same way as the sample No. 71 but has no oxidizing treatment applied; and the sample No. 73 was prepared by applying no oxidizing treatment to conventional carburized material.

The elongation and specific abrasion loss of the samples representing the aforementioned embodiments and references examples were measured.

The tensile test pieces, their straight portions having a diameter of 5mm and a length of 15mm, were cut from the samples. Tensometers were disposed at 10mm intervals on the straight portions. The test pieces were pulled at room temperature and at the rate of 1mm/s, while a chart was prepared. Then the elongations were read from the chart.

The measurement of specific abrasion loss was made as follows: test pieces having a diameter of 5mm and a length of 8mm were taken from the samples. The abrasion test was carried out by using a three-point type pin-on disc abrasion tester, second pieces of carburized SCM415, and spindle oil as lube oil, under a state of a face pressure of 2MPa, a sliding speed of 1m/sec. and an oil temperature of 100°C. The time duration of the abrasion test was one hour, during which the first test pieces were slid against the second pieces.

The desired results of the abrasion tests are shown in Table 7. The criterion elongation for evaluation is set as 0.5% or more. The desired criterion abrasion loss of both the test piece and the second piece is set as less than 0.1, provided that the abrasion loss is 1 when these test pieces are composed of 50at.% of titanium, 48at.% of aluminum and 2at.% of manganese without oxidizing treatment applied thereon.

TABLE 7

SAMPLE NO.	COMPOSITION OF Ti-Al SYSTEM INTERMETALLIC COMPOUND [at.%]		OXIDATION TREATMENT		OXIDE FILM THICKNESS & ELONGATION		SPECIFIC ABRASION LOSS		REMARKS
	Ti,Al,Mn	HALOGEN	TEMP. °C	TIME MIN.	μm	%	TEST PIECE	SECOND PIECE	
47	Ti-27Al	0.05F	850	5	22	0.5	0.02	0.01	—
48	Ti-50Al	0.1 Cl	950	100	7	1.2	0.01	0.01	—
49	Ti-72Al	0.3 Br	825	720	15	0.5	0.01	0.01	—
50	Ti-47Al	0.004F	800	30	1.5	1.0	0.01	0.01	RELATIVELY SMALL AMOUNT OF FLUORINE
51	Ti-47Al	1F	1100	600	4	0.5	0.01	0.01	RELATIVELY LARGE AMOUNT OF FLUORINE
52	Ti-41Al	0.005Cl	850	1400	40	0.9	0.01	0.01	RELATIVELY SMALL AMOUNT OF CHLORINE
53	Ti-47Al	0.9Cl	900	600	3	0.9	0.02	0.01	RELATIVELY LARGE AMOUNT OF CHLORINE
54	Ti-47Al	0.006Br	890	60	3	0.9	0.01	0.01	RELATIVELY SMALL AMOUNT OF BROMINE
55	Ti-47Al	0.9Br	1000	150	5	0.7	0.01	0.01	RELATIVELY LARGE AMOUNT OF BROMINE
56	Ti-47Al	0.005I	800	10	37	1.0	0.01	0.01	RELATIVELY SMALL AMOUNT OF IODINE
57	Ti-47Al	0.4I	900	600	25	0.7	0.01	0.01	APPROPRIATE AMOUNT OF IODINE
58	Ti-47Al	0.8I	1000	10	40	0.5	0.01	0.01	RELATIVELY LARGE AMOUNT OF IODINE

TABLE 7 (CONTINUED)

SAMPLE NO.	COMPOSITION OF Ti-Al SYSTEM INTERMETALLIC COMPOUND [at.%]		OXIDATION TREATMENT		OXIDE FILM THICKNESS & ELONGATION		SPECIFIC ABRASION LOSS		REMARKS
	Ti,Al,Mn	HALOGEN	TEMP. °C	TIME MIN.	μm	%	TEST PIECE	SECOND PIECE	
59	Ti-47Al	0.02F +0.3Cl	900	1200	3	0.5	0.01	0.01	TWO KINDS OF HALOGEN
60	Ti-47Al	0.4Br +0.09I	900	600	10	0.5	0.01	0.01	TWO KINDS OF HALOGEN
61	Ti-47Al	0.3F +0.02B +0.2I	1000	1800	4	0.5	0.01	0.01	THREE KINDS OF HALOGEN
62	Ti-49Al-0.1Mn	0.005F	980	30	3	0.7	0.01	0.01	---
63	Ti-47Al-3Mn	0.2Cl	900	300	5	1.6	0.01	0.01	---
64	Ti-41Al-9Mn	0.8I	850	1400	40	0.9	0.01	0.01	---

TABLE 8

SAMPLE NO.	COMPOSITION OF Ti-Al SYSTEM INTERMETALLIC COMPOUND [at.%]		OXIDATION TREATMENT		OXIDE FILM THICKNESS & ELONGATION		SPECIFIC ABRASION LOSS		REMARKS
	Ti,Al,Mn	HALOGEN	TEMP. °C	TIME MIN.	μm	%	TEST PIECE	SECOND PIECE	
65	Ti-24Al	0.05F	850	5	60	0.5	0.3	0.4	SMALL AMOUNT OF ALUMINUM
66	Ti-77Al	0.1Cl	950	100	7	0.1	0.01	0.01	LARGE AMOUNT OF ALUMINUM
67	Ti-39Al-11Mn	0.8I	825	720	45	1.1	0.2	0.2	LARGE AMOUNT OF MANGANESE
68	Ti-50Al	0.003F	980	30	200	1.5	1.1	0.9	SMALL AMOUNT OF FLUORINE
69	Ti-47Al-3Mn	1.2Cl	900	300	10	0.1	0.01	0.01	LARGE AMOUNT OF FLUORINE
70	Ti-48Al-2Mn	1.1I	975	150	85	0.1	0.2	0.3	THICK FILM
71	Ti-48Al-2Mn	---	955	1000	210	1.6	1.3	1.0	NO HALOGEN
72	Ti-48Al-2Mn					1.6	1	1	NO OXIDATION
73	SCM415					--	1.0	1.0	CARBURIZED STEEL
74	Ti-47Al	1.1F	950	120	3	0.2	0.01	0.01	LARGE AMOUNT OF FLUORINE
75	Ti-47Al	1.001Cl	950	600	140	1.5	0.5	0.2	SMALL AMOUNT OF CHLORINE

TABLE 8 (CONTINUED)

SAMPLE NO.	COMPOSITION OF Ti-Al SYSTEM INTERMETALLIC COMPOUND [at.%] Ti,Al,Mn	HALOGEN	OXIDATION TREATMENT TEMP. °C	TIME MIN.	OXIDE FILM THICKNESS & ELONGATION μm	%	SPECIFIC ABRASION LOSS TEST PIECE	SECOND PIECE	REMARKS
76	Ti-47Al	0.001Br	875	100	130	1.5	0.3	1.0	SMALL AMOUNT OF BROMINE
77	Ti-47Al	1.1Br	1000	20	3	0.1	0.01	0.01	LARGE AMOUNT OF BROMINE
78	Ti-47Al	0.001I	900	1200	155	1.4	0.9	0.9	SMALL AMOUNT OF IODINE
79	Ti-47Al	1.3I	900	1000	50	0.1	0.01	0.01	LARGE AMOUNT OF IODINE
80	Ti-47Al	0.5F	750	1440	1	0.5	0.9	0.8	LOW TREATMENT TEMPERATURE
81	Ti-47Al	0.5F	1150	20	240	0.5	1.4	1.0	HIGH TREATMENT TEMPERATURE

As shown in Tables 7 and 8, the sample Nos. 47-64 embodying the invention desirably attain the criterion values of elongation and specific abrasion loss. The samples of the embodiments are provided with the desired ductility of a metal member and have superior oxidation resistance. The small abrasion losses of both the test pieces and the second pieces are desirable, but it is also desirable that only the test pieces have a small abrasion loss.

On the other hand, the sample Nos. 65-81 of the reference examples have undesirable elongation and specific abrasion loss.

The sample Nos. 54 and 57 contain a large amount of aluminum and halogen and have a superior wear resistance, but have a relatively small elongation. Therefore, they are substantially undesirable as metal members.

This invention has been described above with reference to preferred embodiments as shown in the tables. Modifications and alterations may become apparent to one skilled in the art upon reading and understanding the specification.

In the embodiments, the solid halogen compound was laid on the surface of the Ti-Al system intermetallic compound and heated to its melting point or higher temperature. Alternatively, the solution, sol, gel, or other liquid substance containing the halogen compound, can be applied onto the surface of the Ti-Al system intermetallic compound and heated. No restrictions are made as long as a specified amount of the halogen compound is laid on the intermetallic compound before heating.

As aforementioned, since the Ti-Al system intermetallic compound contains a specified amount of the halogen element, the intermetallic compound can be provided with excellent oxidation resistance. Thus, a preferably lightweight, heat-resistant material can be obtained.

Especially, the intermetallic compound containing a specified amount of at least one selected from the group consisting of niobium, molybdenum, wolfram and silicon can have a further enhanced oxidation resistance.

The intermetallic compound containing a specified amount of at least one selected from the group consisting of manganese, chromium and vanadium can have a further enhanced elongation.

During the surface treatment of a Ti-Al system intermetallic compound, the heating process is carried out at a specified temperature in the gas mixture including a specified amount of halogen and oxygen. Alternatively, the heating

process is carried out by placing a specified amount of halogen on the part requiring oxidation resistance of the Ti-Al system intermetallic compound, and heating the intermetallic compound at a specified temperature for a specified time period. Thus, a dense aluminum oxide film can be formed on the surface of the intermetallic compound. The film can hinder the titanium system oxide from growing. Thus, the oxidation resistance of the Ti-Al system intermetallic compound can be enhanced.

Consequently, as aforementioned, the Ti-Al system intermetallic compound can be easily manufactured.

Additionally, a dense aluminum oxide film having a specified thickness is formed on the surface of the intermetallic compound member. Since the intermetallic compound member is highly resistant to wear and is also lightweight, it is an appropriate sliding component for use in automobiles, for example.

In a method of manufacturing a Ti-Al system intermetallic compound member, a base consisting of aluminum, halogen and titanium is heated and retained at a specified temperature in the oxidizing atmosphere. Thus, a dense aluminum oxide film having a superior wear resistance can be easily formed on the surface of the base.

If the Ti-Al system intermetallic compound includes a specified amount of manganese, the ductility of the compound is further enhanced.

A Ti-Al system intermetallic compound comprised of 25at.% to 75at.% of aluminum and the remainder of titanium. The compound includes 0.004at.% to 1.0at.% each of at least one halogen element selected from the group consisting of fluorine, chlorine, bromine and iodine. Alternatively, to provide a Ti-Al system intermetallic compound with oxidation resistance, the surface of the Ti-Al system intermetallic compound is heated to 800°C to 1125°C in a mixture of gas including 2ppm to 1% by volume of at least one halogen element selected from the group consisting of fluorine, chlorine, bromine and iodine, and also including 0.1% by volume or more of oxygen. Thus, a dense aluminum oxide film is formed on the surface of the intermetallic compound. Alternatively, to form the dense aluminum oxide film, at least one halogen element is first disposed on the part providing the oxidation resistance of the intermetallic compound, and heated for 0.2 hour or longer at 800°C to 1125°C. In this case, the halogen amount should be between 0.002 mol/m^2 and 2 mol/m^2.

Claims

1. A Ti-Al system intermetallic compound comprising substantially titanium and aluminum, and
said Ti-Al system intermetallic compound having at least a surface layer including from 0.004 at.% to 1.0 at.% of at least one halogen element selected from the group consisting of fluorine, chlorine, bromine and iodine.

2. A Ti-Al system intermetallic compound according to claim 1, wherein said Ti-Al system intermetallic compound comprises from 25 at.% to 75 at.% of aluminum and the remainder of said Ti-Al system intermetallic compound is titanium.

3. A Ti-Al system intermetallic compound according to claim 1, wherein said Ti-Al system intermetallic compound further comprises from 25 at.% to 75 at.% of aluminum, from 0.5 at.% to 3 at.% of at least one element selected from the group consisting of niobium, molybdenum, silicon and tungsten and the remainder of said Ti-Al system intermetallic compound is titanium.

4. A Ti-Al system intermetallic compound according to claim 1, wherein said Ti-Al system intermetallic compound further comprises from 25 at.% to 75 at.% of aluminum, from 0.5 at.% to 3 at.% of at least one element selected from the group consisting of niobium, molybdenum and silicon, from 0.5 at.% to 3 at.% of at least one element selected from the group consisting of manganese, chromium and vanadium and the remainder of said Ti-Al system intermetallic compound is titanium.

5. An article formed from a Ti-Al system intermetallic compound according to any of the preceding claims.

6. An article according to claim 5 having superior wear resistance characteristics, said product comprising from 25 at.% to 75 at.% of aluminum, and
having a dense aluminum oxide film, having a thickness between 1 µm and 50 µm, formed on desired surface of the product requiring wear resistance.

7. An article according to claim 6, wherein said product further includes from 0.05 at.% to 10 at.% of manganese.

8. A method of manufacturing an article from a Ti-Al intermetallic compound, comprising titanium and aluminum, said method comprising the steps of:

combining titanium and aluminum with one another to form a Ti-Al system intermetallic compound;
combining at least one halogen element selected from the group consisting of fluorine, chlorine, bromine and iodine in an amount from 0.004 at.% to 1.0 at.% with the Ti-Al intermetallic compound;
forming the combined Ti-Al intermetallic compound into a desired shape to produce an article; and
oxidizing a desired surface of the produced article.

9. A method according to claim 8, wherein the step of combining the at least one halogen element with the Ti-Al intermetallic compound comprises:

using a gas mixture, including 2 ppm to 1% by volume, of the at least one halogen element and including at least 0.1% by volume of oxygen,
heating the desired surface of the Ti-Al system intermetallic compound to between 800°C and 1125°C in the gas mixture to form a dense aluminum oxide film on the desired surface of the Ti-Al system intermetallic compound.

10. A method according to claim 8, wherein the step of combining the at least one halogen element with the Ti-Al intermetallic compound comprises:

placing a halogen compound in an amount between 0.002 mol/m^2 and 2 mol/m^2, including the at least one halogen element, on the surface of the produced product requiring oxidation resistance;
heating the Ti-Al system intermetallic compound to between 800°C to 1125°C for at least 0.2 hours to form a dense aluminum oxide film on the desired surface of the Ti-Al system intermetallic compound.

11. A method according to claim 10, further comprising the step of heating said Ti-Al system intermetallic compound in air.

12. A method according to claim 8, wherein the step of combining the at least one halogen element with the Ti-Al intermetallic compound comprises:

placing a halogen compound, including the at least one halogen element, in solid form on the surface of the article of the Ti-Al system intermetallic compound requiring oxidation resistance, and
heating the halogen compound to at least the halogen compound's melting temperature to form a dense aluminum oxide film on the desired surface.

13. A method according to claim 8, wherein the step of combining the at least one halogen element with the Ti-Al intermetallic compound comprises:

placing a halogen compound, including the at least one halogen element, in liquid form on the surface of the article of the Ti-Al system intermetallic compound requiring oxidation resistance, and
heating the halogen compound to at least the halogen compound's melting temperature to form a dense aluminum oxide film on the desired surface.

14. A method according to claim 8, wherein the step of combining the at least one halogen element with the Ti-Al metallic compound comprises intermixing the halogen element with the Ti-Al metallic compound to form a mixture thereof prior to forming the metallic compound into a desired shape and oxidizing a desired surface of the produced article.

15. A method according to claim 8, wherein the step of combining the at least one halogen element with the Ti-Al system intermetallic compound comprises using from 25 at.% to 75 at.% of aluminum, from 0.004 at.% to 1 at.% of the at least one halogen element and the remainder of the compound is titanium and unavoidable impurities.

16. A method according to claim 8, further comprising the step of heating a Ti-Al system intermetallic compound to 800°C to 1125°C in an oxidizing atmosphere to form a dense aluminum oxide film on the desired surface of the Ti-Al system intermetallic compound.

17. A method acording to claim 16, wherein the step of combining the at least one halogen element with the Ti-Al system intermetallic compound comprises using from 25 at.% to 75 at.% of aluminum, from 0.004 at.% to 1 at.% of the at least one halogen element, from 0.05 at.% to 10 at.% of manganese and the remainder of the compound

is titanium and unavoidable impurities.

Patentansprüche

1. Intermetallische Verbindung des Ti-Al-Systems, im wesentlichen Titan und Aluminium umfassend, und wobei die intermetallische Verbindung des Ti-Al-Systems mindestens eine Oberflächenschicht aufweist, welche 0,004 Atom-% bis 1,0 Atom-% an mindestens einem Halogenelement einschließt, ausgewählt aus der Gruppe, die aus Fluor, Chlor, Brom und Iod besteht.

2. Intermetallische Verbindung des Ti-Al-Systems nach Anspruch 1, wobei die intermetallische Verbindung des Ti-Al-Systems 25 Atom-% bis 75 Atom-% an Aluminium umfaßt, und der Rest der intermetallischen Verbindung des Ti-Al-Systems Titan ist.

3. Intermetallische Verbindung des Ti-Al-Systems nach Anspruch 1, wobei die intermetallische Verbindung des Ti-Al-Systems weiterhin 25 Atom-% bis 75 Atom-% an Aluminium, 0,5 Atom-% bis 3 Atom-% an mindestens einem Element, ausgewählt aus der Gruppe, die aus Niob, Molybdän, Silicium und Wolfram besteht, umfaßt, und der Rest der intermetallischen Verbindung des Ti-Al-Systems Titan ist.

4. Intermetallische Verbindung des Ti-Al-Systems nach Anspruch 1, wobei die intermetallische Verbindung des Ti-Al-Systems weiterhin 25 Atom-% bis 75 Atom-% an Aluminium, 0,5 Atom-% bis 3 Atom-% an mindestens einem Element, ausgewählt aus der Gruppe, die aus Niob, Molybdän und Silicium besteht, 0,5 Atom-% bis 3 Atom-% an mindestens einem Element, ausgewählt aus der Gruppe, die aus Mangan, Chrom und Vanadin besteht, umfaßt, und der Rest der intermetallischen Verbindung des Ti-Al-Systems Titan ist.

5. Gegenstand, gebildet aus einer intermetallischen Verbindung des Ti-Al-Systems nach einem der vorhergehenden Ansprüche.

6. Gegenstand nach Anspruch 5, welcher verbesserte Verschleißbeständigkeitseigenschaften hat, wobei das Produkt 25 Atom-% bis 75 Atom-% an Aluminium umfaßt, und einen dichten Aluminiumoxidfilm mit einer Dicke zwischen 1 µm und 50 µm hat, welcher auf der gewünschten Oberfläche des Produkts gebildet ist, für das Verschleißbeständigkeit gefordert ist.

7. Gegenstand nach Anspruch 6, wobei das Produkt weiterhin 0,05 Atom-% bis 10 Atom-% an Mangan einschließt.

8. Verfahren zur Herstellung eines Gegenstands aus einer intermetallischen Ti-Al-Verbindung, Titan und Aluminium umfassend, wobei das Verfahren die Schritte der

   Vereinigung von Titan und Aluminium miteinander zur Bildung einer intermetallischen Verbindung des Ti-Al-Systems;
   Vereinigung von mindestens einem Halogenelement, ausgewählt aus der Gruppe, die aus Fluor, Chlor, Brom und Iod besteht, in einer Menge von 0,004 Atom-% bis 1,0 Atom-% mit der intermetallischen Ti-Al-Verbindung;
   Formung der vereinigten intermetallischen Ti-Al-Verbindung in eine gewünschte Form zur Herstellung eines Gegenstands; und Oxidation einer gewünschten Oberfläche des hergestellten Gegenstands umfaßt.

9. Verfahren nach Anspruch 8, wobei der Schritt der Vereinigung von mindestens dem einen Halogenelement mit der intermetallischen Ti-Al-Verbindung

   die Verwendung eines Gasgemisches, 2 ppm bis 1 Vol-% an mindestens dem einen Halogenelement und mindestens 0,1 Vol-% an Sauerstoff einschließend,
   das Erhitzen der erwünschten Oberfläche der intermetallischen Verbindung des Ti-Al-Systems auf zwischen 800°C und 1125°C in dem Gasgemisch zur Bildung eines dichten Aluminiumoxidfilms auf der erwünschten Oberfläche der intermetallischen Verbindung des Ti-Al-Systems umfaßt.

10. Verfahren nach Anspruch 8, wobei der Schritt der Vereinigung von mindestens dem einen Halogenelement mit der intermetallischen Ti-Al-Verbindung

   das Aufbringen einer Halogenverbindung in einer Menge zwischen 0,002 mol/m^2 und 2 mol/m^2, mindestens

das eine Halogenelement einschließend, auf die Oberfläche des hergestellten Produkts, für das Oxidationsbeständigkeit gefordert ist;
das Erhitzen der intermetallischen Verbindung des Ti-Al-Systems auf zwischen 800°C und 1125°C für mindestens 0,2 Stunden zur Bildung eines dichten Aluminiumoxidfilms auf der erwünschten Oberfläche der intermetallischen Verbindung des Ti-Al-Systems umfaßt.

11. Verfahren nach Anspruch 10, welches weiterhin den Schritt des Erhitzens der intermetallischen Verbindung des Ti-Al-Systems an der Luft umfaßt.

12. Verfahren nach Anspruch 8, wobei der Schritt der Vereinigung von mindestens dem einen Halogenelement mit der intermetallischen Ti-Al-Verbindung

das Aufbringen einer Halogenverbindung, mindestens das eine Halogenelement einschließend, in fester Form auf die Oberfläche des Gegenstands aus der intermetallischen Verbindung des Ti-Al-Systems, für welchen Oxidationsbeständigkeit gefordert ist, und
das Erhitzen der Halogenverbindung auf mindestens die Schmelztemperatur der Halogenverbindung zur Bildung eines dichten Aluminiumoxidfilms auf der erwünschten Oberfläche umfaßt.

13. Verfahren nach Anspruch 8, wobei der Schritt der Vereinigung von mindestens dem einen Halogenelement mit der intermetallischen Ti-Al-Verbindung

das Aufbringen einer Halogenverbindung, mindestens das eine Halogenelement einschließend, in flüssiger Form auf die Oberfläche des Gegenstands aus der intermetallischen Verbindung des Ti-Al-Systems, für den Oxidationsbeständigkeit gefordert ist, und
das Erhitzen der Halogenverbindung auf mindestens die Schmelztemperatur der Halogenverbindung zur Bildung eines dichten Aluminiumoxidfilms auf der erwünschten Oberfläche umfaßt.

14. Verfahren nach Anspruch 8, wobei der Schritt der Vereinigung von mindestens dem einen Halogenelement mit der Ti-Al-Metallverbindung das Durchmischen des Halogenelements mit der Ti-Al-Metallverbindung unter Bildung eines Gemisches davon vor der Formung der Metallverbindung in eine gewünschte Form und der Oxidation einer erwünschten Oberfläche des hergestellten Gegenstands umfaßt.

15. Verfahren nach Anspruch 8, wobei der Schritt der Vereinigung von mindestens dem einen Halogenelement mit der intermetallischen Verbindung des Ti-Al-Systems die Verwendung von 25 Atom-% bis 75 Atom-% an Aluminium, 0,004 Atom-% bis 1 Atom-% an mindestens dem einen Halogenelement umfaßt, und der Rest der Verbindung Titan und unvermeidbaren Verunreinigungen sind.

16. Verfahren nach Anspruch 8, welches weiterhin den Schritt des Erhitzens einer intermetallischen Verbindung des Ti-Al-Systems auf 800°C bis 1125°C in einer oxidierenden Atmosphäre zur Bildung eines dichten Aluminiumoxidfilms auf der erwünschten Oberfläche der intermetallischen Verbindung des Ti-Al-Systems umfaßt.

17. Verfahren nach Anspruch 16, wobei der Schritt der Vereinigung von mindestens dem einen Halogenelement mit der intermetallischen Verbindung des Ti-Al-Systems die Verwendung von 25 Atom-% bis 75 Atom-% an Aluminium, 0,004 Atom-% bis 1 Atom-% an mindestens dem einen Halogenelement, 0,05 Atom-% bis 10 Atom-% an Mangan umfaßt, und der Rest der Verbindung Titan und unvermeidbaren Verunreinigungen sind.

Revendications

1. Composé intermétallique du système Ti-Al, comprenant essentiellement du titane et de l'aluminium, et ledit composé intermétallique du système Ti-Al ayant au moins une couche de surface comprenant de 0,004 % at. à 1,0 % at. d'au moins un élément halogéné sélectionné dans le groupe comprenant le fluor, le chrome, le brome et l'iode.

2. Composé intermétallique du système Ti-Al selon la revendication 1, dans lequel ledit composé intermétallique du système Ti-Al comprend de 25 % at. à 75 % at. d'aluminium et le restant dudit composé intermétallique du système Ti-Al étant constitué de titane.

3. Composé intermétallique du système Ti-Al selon la revendication 1, dans lequel ledit composé intermétallique du système Ti-Al comprend en outre de 25 % at. à 75 % at. d'aluminium, de 0,5 % at. à 3,0 % at. d'au moins un élément sélectionné dans le groupe comprenant le niobium, le molybdène, le silicium et le tungstène, et le restant dudit composé intermétallique du système Ti-Al étant constitué de titane.

4. Composé intermétallique du système Ti-Al selon la revendication 1, dans lequel ledit composé intermétallique du système Ti-Al comprend en outre de 25 % at. à 75 % at. d'aluminium, de 0,5 % at. à 3,0 % at. d'au moins un élément sélectionné dans le groupe composé du niobium, molybdène et silicium, de 0,5 % at. à 3,0 % at. d'au moins un élément sélectionné dans le groupe comprenant le manganèse, le chrome et le vanadium et le restant dudit composé intermétallique du système Ti-Al étant constitué de titane.

5. Article formé à partir d'un composé intermétallique du système Ti-Al selon l'une quelconque des revendications précédentes.

6. Article selon la revendication 5, ayant des caractéristiques de résistance élevées à l'usure, ledit produit comprenant de 25 % at. à 75 % at. d'aluminium et
ayant un film dense en oxyde d'aluminium, présentant une épaisseur comprise dans la plage allant de 1 mm à 50 mm, formé sur une surface souhaitée du produit nécessitant une résistance à l'usure.

7. Article selon la revendication 6, dans lequel ledit produit comprend en outre de 0,5 % at. à 10 % at. de manganèse.

8. Procédé de fabrication d'un article à partir d'un composé intermétallique du système Ti-Al, comprenant du titane et de l'aluminium, ledit procédé comprenant les étapes de :

combinaison de titane et d'aluminium entre eux pour former un composé intermétallique du système Ti-Al;

combinaison d'au moins un élément halogéné sélectionné dans le groupe comprenant le fluor, le chlore, le brome et l'iode, en une quantité comprise dans la plage allant de 0,004 % at. à 1,0 % at, avec le composé intermétallique du système Ti-Al;

formation du composé combiné intermétallique du système Ti-Al selon la forme souhaitée pour produire un article; et

oxydation d'une surface souhaitée de l'article produit.

9. Procédé selon la revendication 8, dans lequel l'étape de combinaison du au moins un élément halogéné avec le composé intermétallique du système Ti-Al comprend :

l'utilisation d'un mélange de gaz, comprenant de 2 ppm à 1 % en volume du au moins un élément halogéné et comportant au moins 0,1 % en volume d'oxygène,

le chauffage de la surface souhaitée du composé intermétallique du système Ti-Al à une température comprise dans la plage allant de 800 °C à 1125 °C, dans le mélange de gaz, pour former un film dense d'oxyde d'aluminium sur la surface souhaitée du composé intermétallique du système Ti-Al.

10. Procédé selon la revendication 8, dans lequel l'étape de combinaison du au moins un élément halogéné avec le composé intermétallique du système Ti-Al comprend :

la mise en place d'un composé halogéné en une quantité comprise dans la plage allant de 0,002 mol/m^2 à 2 mol/m^2, comprenant le au moins un élément halogéné, sur la surface du produit obtenu nécessitant une résistance à l'oxydation;

le chauffage du composé intermétallique du système Ti-Al à une température comprise dans la plage allant de 800 °C à 1125 °C, pendant au moins 0,2 heure, pour former un film dense d'oxyde d'aluminium sur la surface souhaitée du composé intermétallique du système Ti-Al.

11. Procédé selon la revendication 10, comprenant en outre l'étape de chauffage dans l'air dudit composé intermétallique du système Ti-Al.

12. Procédé selon la revendication 8, dans lequel l'étape de combinaison du au moins un élément halogéné avec le composé intermétallique du système Ti-Al comprend :

    la mise en place d'un composé halogéné, comprenant le au moins un élément halogéné, sous une forme massive sur la surface de l'article du composé intermétallique du système Ti-Al nécessitant une résistance à l'oxydation, et

    le chauffage du composé halogéné à la température de fusion du au moins un composé halogéné, pour former un film dense d'oxyde d'aluminium sur la surface souhaitée.

13. Procédé selon la revendication 8, dans lequel l'étape de combinaison du au moins un élément halogéné avec le composé intermétallique du système Ti-Al comprend :

    la mise en place d'un composé halogéné, comprenant le au moins un élément halogéné, sous une forme liquide sur la surface de l'article du composé intermétallique du système Ti-Al nécessitant une résistance à l'oxydation, et

    le chauffage du composé halogéné à la température de fusion du au moins un composé halogéné, pour former un film dense d'oxyde d'aluminium sur la surface souhaitée.

14. Procédé selon la revendication 8, dans lequel l'étape de combinaison du au moins un élément halogéné avec le composé métallique du système Ti-Al comprend le mélange de l'élément halogéné avec le composé métallique du système Ti-Al, pour former un mélange avant la formation du composé métallique sous une forme souhaitée et l'oxydation d'une surface souhaitée de l'article produit.

15. Procédé selon la revendication 8, dans lequel l'étape de combinaison du au moins un élément halogéné avec le composé intermétallique du système Ti-Al comprend l'utilisation de 25 % at. à 75 % at. d'aluminium, de 0,004 % at. à 1% at. du au moins un élément halogéné et le restant du composé étant constitué de titane et d'impuretés inévitables.

16. Procédé selon la revendication 8, comprenant en outre l'étape de chauffage d'un composé intermétallique du système Ti-Al à une température comprise dans la plage allant de 800 °C à 1125 °C, dans une atmosphère oxydante, pour former un film dense d'oxyde d'aluminium sur la surface souhaitée du composé intermétallique du système Ti-Al.

17. Procédé selon la revendication 16, dans lequel l'étape de combinaison du au moins un élément halogéné avec le composé intermétallique du système Ti-Al comprend l'utilisation de 25 % at. à 75 % at. d'aluminium, de 0,004 % at. à 1 % at. du au moins un élément halogéné, de 0,05 % at. à 10 % at. de manganèse, et le restant du composé étant constitué de titane et d'impuretés inévitables.